LLNL-TR-455071

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Bounding Accident Analysis for LLNL BSL-3 Facility

M. Johnson

September 14, 2010

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Introduction

In the bounding accident analysis for the Environmental Assessment (EA) for the LLNL Biosafety Level 3 (BSL-3) Facility (Ref. 1), the accident scenario used was essentially the same as that used by the Department of the Army in its Final Programmatic Environmental Impact Statement (PEIS) for the United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Ft. Detrick, Maryland (Ref. 2).

In a recent review of the PEIS by the National Research Council (NRC), (Ref. 3), the accident analysis was criticized because the mathematical model used to calculate the potential biological release was proprietary and therefore not available to the NRC to make an independent determination. An attempt by the NRC to reproduce the findings using a different model did not produce the same result.

In view of the NRC criticism, it was decided to re-examine the consequences of the LLNL BSL-3 bounding accident using a publicly accessible dispersion model. This current evaluation uses the Hotspot Health Physics Code (Ref. 4), a Department of Energy (DOE)-developed, publicly accessible Gaussian plume-dispersion model. Hotspot was developed by DOE as a tool for performing radiological event atmospheric dispersion consequence analysis. It is a companion dispersion model for the National Atmospheric Release Advisory Center (NARAC), which provides tools and services to the Federal Government that map the probable spread of hazardous material accidentally or intentionally released into the atmosphere. Hotspot is included as part of the DOE Safety Analysis Tool Chest for performance of Nuclear Safety Analysis calculations.

LLNL BSL-3 Accident Scenario

The accident scenario, as described in the EA, involves a release of a rickettsial microorganism, *Coxiella burnetii* (*C. burnetii*), which causes Q fever. A worker places one liter of *C. burnetii* slurry into six 250-mL polypropylene centrifuge tubes (165 milliliters per tube). The worker fails to insert the O-rings or tighten the screw-on centrifuge caps. The centrifuge, which is not in a biosafety cabinet, is turned on. All six tubes leak - with some of the slurry leaking into the rotor and some of it leaking into the centrifuge compartment.

It would not be credible to attribute more than 1% to 10% of the slurry leaking past an improperly sealed centrifuge tube. It is assumed 10% of the slurry (100 mL) leaks from the tubes.

It is likely that substantially more slurry leaking past improperly sealed caps would vent out and into the centrifuge cabinet than into the covered rotor. From this it may credibly be assumed that 1% of the slurry leaking from the tubes (1 mL) leaks onto the rotor – with the remaining slurry (99 mL) leaking into the centrifuge cabinet.

The scenario postulates that most (99%) of the slurry that leaked into the covered rotor is not aerosolized. Then the amount aerosolized would be 1% of 1 mL = 0.01 mL.

The scenario also postulates that only a fraction of the slurry that leaked into the centrifuge cabinet is aerosolized and 90% of that settles as droplets inside the chamber. It is credible to assume that, as with the covered rotor, 1 % of the slurry leaking into the centrifuge cabinet becomes aerosolized: 1% of 99 mL = 0.99 mL. Of this, 90% settles out as droplets inside the chamber and the remaining 10% is released as an aerosol: 10% of 0.99 mL = 0.099 mL.

Then the total quantity of aerosolized slurry released to the room upon opening the centrifuge lid would be 0.01 + 0.099 = 0.109 mL, approximately 0.11 mL.

The slurry is postulated to be thixotropic (much like egg white), with about 20% dry solids. Serum-albumin (crystalline) has a documented concentration by weight of 22%, with a solution density of 1.065 g/cc (Ref. 5). This appears consistent with the slurry description. Applying the serum-albumin solution density, the mass of the aerosolized slurry solids would be: 20% x 0.11 mL x 1.065 g/cc = 0.023 g.

Conservatively applying, in this case, the upper estimate for the number of *B. anthracis* spores per gram estimated in the 2001 terrorist attack involving letters sent to the Senate, 2 g of dry material could contain up to 1E12 organisms (Ref. 6), or 5E11 organisms per gram. Then the number of aerosolized *C. burnetii* organisms released to the room would be: 2.3E-2 x 5E11 = 1.2E10 organisms.

The estimated human infective dose (HID) with a 25 to 50 percent chance of contracting the disease through the inhalation route for Q fever is 10 organisms (Ref. 7). Then the number of HID_{50} aerosolized would be 1.2E10 organisms x 1 HID_{50} / 10 organisms = 1.2E9 HID_{50} aerosolized.

As stated in the accident scenario, the percent aerosol recovery (the percent of infectious doses of *C. burnetii* rendered airborne in a one- to five-micron particle size) representing the maximum infectivity for man is determined conservatively to be 0.1 percent. Thus the number of infectious aerosolized doses would be 0.1% x 1.2E9 HID_{50} = 1.2E6 HID_{50}.

<u>Source Term for the Dispersion Analysis</u>

The Source Term (ST) is the amount of material (in this case *C. burnetii* in terms of HID_{50}) released to the air. The airborne source term is typically estimated by the following five-component linear equation (Ref. 8):

ST = MAR x DR x AF x RF x LPF

where:

ST = Source Term
MAR = Material-at-Risk
DR = Damage Ratio

AF	= Airborne Fraction
RF	= Respirable Fraction
LPF	= Leak Path Factor

The maximum number of aerosolized infectious doses of *C. burnetii* presented to the exhaust filters is: MAR x DR x AF = 1.2E6 HID_{50}

The air in the BSL-3 laboratory room in which the postulated accident takes place exhausts via two filters in series which are conservatively estimated to have 95% particulate removal efficiency, and then exits through a roof stack. Thus all but 5% of the material is captured by the filters and the LPF = 0.05. The lung retention of respirable particles is determined to be one half or less of the intake: RF $\leq$ 0.5.

Then the Source Term is:

ST = 0.05 x 0.5 x 1.2E6 HID_{50} = 3E4 HID_{50} *C. burnetii.*

<u>Dispersion Analysis</u>

Scenario Assumptions and Input

- Daytime event
- Release height = 0.0 m
- Pasquill stability class D, open (rural) terrain
- Mixing layer height = 100 m
- Wind speed = 4.5 mph (2.1 m/s) - as measured at 3 m
- Deposition velocity = 0.1 cm/s
- Organism die-off rate = ~1%/minute ($t_{1/2}$ = 70 minutes)
- Release Duration = Exposure Duration = Sample Time = 1.2 minutes
- Receptors of interest = 100 m and 810 m downwind from the exhaust stack.
- Receptor height = 0.0 m
- Maximally exposed individual breathing rate = 15 L/min (2.5E-4 m^3/s).

<u>Dispersion Analysis Results</u>

The dispersion analysis results in Table 1 provide an estimate for potential exposure to the public for the postulated accident scenario.

Table 1 : Dispersion Analysis Results

DISTANCE [Km]	χ/Q NORMALIZED ATMOSPHERIC DISPERSION COEFFICIENT [sec/m3]	χ RESPIRABLE TIME-INTEGRATED AIR CONCENTRATION [HID_{50}-sec/m3]	RESPIRABLE AIR CONCENTRATION [HID_{50}/L]	RESPIRABLE DOSE [HID_{50}]
0.016	2.10E-01	6.3E+03	8.4E-02	1.6E+00
0.038	3.80E-02	1.1E+03	1.5E-02	2.8E-01
0.100	5.60E-03	1.7E+02	2.2E-03	4.2E-02
0.810	1.10E-04	3.4E+00	4.5E-05	8.4E-04

Estimated Potential Dose Concentration to the Public:

- The dose concentration calculated at 16 m of 0.084 HID_{50}/L is consistent with the dose concentration result at 16 m of <0.1 HID_{50}/L presented in the EA.
- The dose concentration calculated at 38 m of 0.015 HID_{50}/L is consistent with the dose concentration result at 38 m of <0.01 HID_{50}/L presented in the /EA.
- It is further shown that the dose concentrations applicable to the nearest public receptor to the LLNL BSL-3 Facility would be 4.5E-05 HID_{50}/L.

Estimated Potential Dose to the Public:

- For the postulated accident, there would be sufficient respirable *C. burnetii* at 16 meters from the exhaust stack to represent slightly greater than one airborne human infective dose at a 50 percent rate for contracting the disease. It is predicted that beyond 20 meters human receptors would receive less than one HID_{50}.
- As previously noted, per the CDC, the HID_{50} for *C. burnetii* is 10 organisms. If the minimum infective dose (MID) is represented by a single organism, then it is predicted that human receptors at 100 m and beyond would receive well below the MID for the postulated accident scenario.

<u>Conclusion</u>

The conclusion of this evaluation is that the consequence estimates in the EA can be reproduced using a public-accessible Gaussian plume-dispersion model and conservative modeling assumptions consistent with the accident scenario postulated in the EA. Also, the potential consequences to the public for the postulated accident would be far below the minimum infectious dose of one organism.

References:

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[i] Calculations is this report were performed by Safety Analyst Mark Johnson, LLNL Safety Basis Division (August 2010)